

Braddock Dam Float-In Construction Hydraulics and Hydrology Lessons Learned

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Abstract

The float-in dam at Monongahela River Locks and Dam 2 near Braddock, PA was the first of its kind for the Corps of Engineers. Many construction advantages and cost savings can be attributed to this float-in/in-the-wet construction. The Monongahela River Locks and Dam 2 construction required extensive numerical and physical hydraulic modeling. Physical modeling was performed by the Waterways Experiment Station (WES) located in Vicksburg, Mississippi. WES is the headquarters for the U.S. Army Engineer Research and Development Center (ERDC). The delivery, alignment and set down of the two dam segments were critical elements of this project. Variations in the plan of action developed and presented many challenges for the Hydraulics and Hydrology team.

Forecasting & Decision Tools

Hydrologic forecasting and decision-making tools were a vital part of the float-in construction and were updated and fine-tuned early in the design process. The initial construction schedules suggested that the dam segment transports would take place during the summer and fall low flow period; segment movement actually took place during the winter. Cold weather did not pose a problem during segment set-down, however, ice and snow should be considered.

Plans were developed for future construction schedule changes and hydraulics and hydrology data for all seasons were on hand. Highly accurate and updated seasonal flow and stage durations were developed and utilized for construction decisions. Rating curves were developed for all major construction activities and phases. Since segment transport and set-down were extremely dependent on river flows, it was imperative to upgrade our river forecasting models and fine tune them for all seasonal conditions. To aid in the forecast modeling, the rain and stream gage network for the Monongahela River basin was upgraded with several new state-of-the-art gages at strategic locations. These enhancements to the gage network provided advanced notice and refined information of changing conditions cause by rainfall, snowmelt and hydropower releases.

Scour & Sedimentation

The foundation areas and delivery channel for the Monongahela River Locks and Dam 2 project float-in construction segments had to be clear of all sedimentation during the set-down process. Actual sediment gradation and river yield data was collected and developed early in the design. The magnitude and frequency of silting

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of the project area was estimated from HEC-6 modeling. Although the Monongahela River is relatively clean due to its gravel bed with little sediment, the foundation area had to be cleared several times. The duration to clean the foundation was important because it eliminated several windows of opportunity, causing several set-down schedule setbacks. The 1:100 scale WES navigation model with a movable bed (the river bed was modeled with sand rather than concrete) near the project was used to evaluate localized scour at the project. This data was useful in the design of required bed and bank protection for temporary construction considerations. Photo 1 shows the 1:100 scale WES navigation model with moveable bed.

Developing the Construction Site

The WES 1:100 scale navigation model was used to develop maximum velocity information at the project site for all major construction activities. Figure 1 shows current patterns around floating segment one; this figure is from the WES study. As a result, the limiting river velocity for riverbed excavation and sheet pile construction was estimated at 4 feet per second (fps); diving activities had a limiting velocity of 2.5 fps. The set-down of the dam segments was limited to a river velocity of 2 fps, which is equivalent to a flow of 25,000 cubic feet per second (cfs). The factors affecting velocity were excavation, segment blockage and high river flows.

Segment Draft

The Monongahela River Locks and Dam 2 project float-in segment drafts were addressed early in the design process. The design draft from the fabrication site (Leetsdale, PA) to the outfitting pier (Duquesne, PA) was 9 feet and 12 feet from the outfitting pier to the project site (Braddock, PA). These drafts were critical because of streambed, fabrication site sill and lock sill restrictions along the delivery path. Good coordination with the construction division provided the hydraulics and hydrology team with early warnings of draft problems. The contractor provided excess thickness at certain members of the segments that increased draft. Both dam segments drafted uneven and deeper than anticipated at the fabrication site. Water was used as a counterweight in various compartments in the dam shell to even the segment drafts. Grout bags were attached to the bottom of each segment; these bags added to the draft problems.

Artificial raising the Ohio River by gate overtopping at Montgomery L/D

Prior to the actual segment float out, a trial run using barges to simulate the size of the segment was performed. The trial run floated the barges from the fabrication site to the outfitting pier and then backed the barges downstream to the dam site allowing the captain to experience the limited visibility and size of the actual segments.

Segment one float out from the fabrication site at Leetsdale to the outfitting pier at Duquesne took place on July 26, 2001 during a low flow period, however recent rainfall helped in acquiring the desired river stages. See Figure 2 for a schematic from the fabrication site at Leetsdale to the outfitting pier at Duquesne; photo 2 shows a segment at the fabrication site. The design draft of 10 feet was exceeded; the actual draft was 10.9 feet. The two main causes for the increase in draft were underestimating the weight of rebar and thicker concrete placement. Four shallow points of concern in the move were: exiting the Leetsdale dry dock (stage =

10.5 feet), Dashields lower guard wall (stage = 11 feet), Emsworth lower guide wall (stage = 9 feet), and in the Emsworth pool downstream of Lock and Dam 2.

To adjust for the sill elevation at Leetsdale and the lower guide wall at Dashields, all gates at Montgomery were closed and allowed to overflow to build the pool an additional foot. See Photo 3, the gates at Montgomery Locks and Dam overflowing. Dredging 1000 – 2000 cubic yards of material at Emsworth resolved the lower guide wall problems; the pool at Emsworth was held high, and the gates were closed further once the segment entered the lock chamber to build up the pool downstream of Lock and Dam 2.

The upper dams on the Monongahela River passed steady flow; Maxwell and Locks and Dam 4 built up pools beforehand to upper gage 10.3 feet (approximately 1 foot above normal pool). Maxwell opened an additional 1-foot and Locks and Dam 4 near Charleroi, PA opened an additional 2 feet for 10 hours starting approximately 8 hours before the segment was expected to reach the shallow area downstream of Lock and Dam 2. The pools were drawn down to send a pulse of water that would arrive at the critical time near the shallow area.

In addition to operations at the locks and dams on the Ohio and Monongahela Rivers, reservoir operations were made to increase depth of flow. Figure 3 is a Pittsburgh District map showing all projects. Kinzua Dam and Allegheny Reservoir, the upper-most reservoir on the Allegheny River, released an additional 500 cfs by opening gates to 9 feet on July 24, 2001. Tygart also opened to 9 feet releasing an additional 2000 cfs on July 24, 2001; Lake Lynn, a privately owned hydropower dam on the Cheat River, passed a steady 800 cfs.

On February 27, 2002 segment two started its journey from Leetsdale to Duquesne during a moderate flow period. The actual draft was deeper than the design draft once again, the design draft was 10 feet and the actual draft was 11.3 feet. Due to the deeper draft of segment two, the target stages for the float-out were 0.5 feet greater than segment one stages. Reservoir and locks and dam operations were utilized to reach the desired draft. On the Ohio River, the gates at Montgomery were both overflowed and underflowed giving a river gage reading of 14.3, and the Emsworth pool was built up prior to the float-out to 17.5 feet and raised to 17.8 feet once segment two entered the lock chamber. The locks and dams at Maxwell and Locks and Dam 4 built up their pools and released from storage drawing down their pools starting 8 hours prior to the segment's arrival at the shallow area downstream of Lock and Dam 2.

As with the first segment, the reservoirs were used to increase depth of flow. On February 26, 2001 Mahoning Creek Lake, Crooked Creek Lake, Conemaugh River Lake, and Loyalhanna Lake released an additional 1400 cfs combined. Tygart Lake released an additional 1400 cfs from February 25 and 26, 2001, and Lake Lynn released 2200 cfs at midnight on February 27, 2001. The total increase in flow from reservoir releases was approximately 5000 cfs.

Artificial raising the Monongahela River during set-down

The segment one set down took place during another low flow period on December 5, 2001. Again the draft of the segment was deeper than the design draft; the design draft was 14 feet while the actual draft was 15.5 feet to 16 feet. The only low spot of

concern between the outfitting pier at Duquesne and the dam site at Braddock was near the railroad bridge where the depth was approximately 15 feet.

As with the initial float out from Leetsdale, a combination of reservoir operations and lock and dam operations needed to take place to reach the target stage of 11.8 feet at Braddock. Starting December 1, 2001 Stonewall Jackson Lake opened its gates to pass an additional 1000 cfs. Tygart Lake opened its gates on December 2, 2001, to allow an additional 540 cfs, on December 3, 2001 Youghiogheny River Lake passed an additional 200 cfs, and on December 4, 2001 Lake Lynn opened to allow an additional 2300 cfs. The total increased flow from the reservoirs was approximately 4000 cfs.

The locks and dams along the Monongahela River built up their pools in advance to be able to draw them down and release a pulse of additional flow at the critical time. At 6:00 PM on December 4 Opekiska, Hildebrand, Morgantown, and Point Marion locks and dams opened to allow a combined 1700 cfs of additional flow. At 9:00 PM Maxwell and Locks and Dam 4 opened to allow an additional 1500 cfs and 1900 cfs, respectively. At 10:00 AM on December 5 the peak pool (stage 11.8) reached Braddock as segment one arrived at the railroad bridge; the pool increased by 1.4 feet. Photo 4 shows Segment 1 at Braddock, PA; also shown in the photo is the existing fixed crest dam.

Segment 2 set-down took place during moderate flow on June 17, 2002. The actual draft was 15.5 feet to 16 feet, while the design draft was 14 feet. The same shallow spot near the railroad bridge existed and the target stage at Braddock was again 11.8 feet. Minimal or no augmentation was needed, only steady flows were required to obtain the target stage. Once segment two was in position for set-down, falling river stages were needed. This was achieved by utilizing the small lock chamber as a floodway at Braddock, after the pool was lowered, the floodway was closed and the lock filling valves were opened to maintain an acceptable range of pool stages.

Section Model

As the float-in design progressed, it became apparent that the most critical velocities, currents and eddies would occur during the segment set-downs. Since the segments were thin (1 foot in some places) and fragile, a 1:30 scale WES model was utilized to study hydraulic phenomenon during the set-down process. The set-down was designed to occur with river flows of up to 25,000 cfs. The first segment had a maximum allowable river velocity of 1.3 fps and the second 2.2 fps. The full range of river discharges were evaluated because the most critical conditions may not have been for the highest flow.

The model was used to determine forces (28-33 kips) needed to hold the segment in place and as it was set-down. These forces were used to size wire rope, winches and dead-men. Although ice and debris loads were not studied in this model, they could have been. The Monongahela Locks and Dam 2 small lock chamber was to be used as a floodway to reduce velocities during set-down, tests indicated an up-river force (5 kips) on the segments occurred when the floodway was opened. This up-river force had to be restrained until the upper pool stabilized. The possible rapid downward movement of a segment induced by high velocities under the segment as it

was sunk into the foundation box was also tested and found to be minimal. The model was also used to size the foundation base stone.

Navigation Model

Since the Monongahela Locks and Dam 2 float-in construction required precise movement and set-down of two large segments (105' wide by 332' long for segment one and 265' long for segment two), for river flows up to 25,000 cfs, it was decided to use the WES Monongahela Locks and Dam 2 Navigation model (1:100 scale) for these tests. The use of the existing small lock chamber as a controlled floodway to help reduce velocities during the set-down was tested and proved useful for river flows between 12,000 and 25,000 cfs. Analyzing the maneuvering of the segments into position was essential due to the size of the segments the narrow approach channel, the segments' fragile construction and the accuracy required to match the segment to the foundation.

Backing the segment down river with the pusher boat was determined to provide the best control. It was found that the pusher boat simply had to increase power and push upstream if any problems were encountered during delivery. The model proved valuable in determining eddies, currents & velocities during segment delivery. Since the segments were thin walled, the model was used to determine if the available push points could be used to adequately position the segments. The size and need for a helper pusher boat was tested and determined to be useful during the delivery for higher discharges. The delivery testing aided in determining the location of river markers required to delineate the location of excavated channel lines leading to the foundation.

The model proved valuable in determining the location of dead-men, anchors and winch points needed for the rotation of segments. The pusher boat, helper boat and turning cable requirements for rotating, holding and setting down the segment in place was optimized for all flow conditions. The model was utilized to determine the hydraulic sliding forces against each segment after it had been set-down but not firmly attached to the foundation. This was accomplished by suspending each segment with rods that had strain-gages to determine the forces for high flows. Sliding forces for the 500-year flood for the first segment was 1100 kips and 900 kips for the second. The overall factor of safety for the segments against sliding was determined to be 3.

Summary

The Float-In Dam Construction Project at Braddock, PA was the first of its kind for the Corps of Engineers; therefore it was a learning experience for all the people involved. Several lessons were learned throughout the project include the need for physical modeling produced by WES. The models were beneficial in determining dredging locations, maneuvering the segments into place, and determining maximum river flows for set-downs. The increased draft caused additional issues for the hydraulics and hydrology team in getting the segments from Leetsdale to Duquesne and then to Braddock. By having all the necessary information on hand, the schedule changes and draft problems were resolved efficiently.



1. WES navigation model with moveable bed, 1:100 scale.



2. Segment at fabrication site, Leetsdale, PA.



3. Montgomery Locks and Dam, gates overflowing to allow for additional depth.



4. Segment 1 at Braddock, PA. Existing fixed crest dam is also shown.

Figure 1. Current patterns around floating segment one; from WES navigation model (1:100 scale).

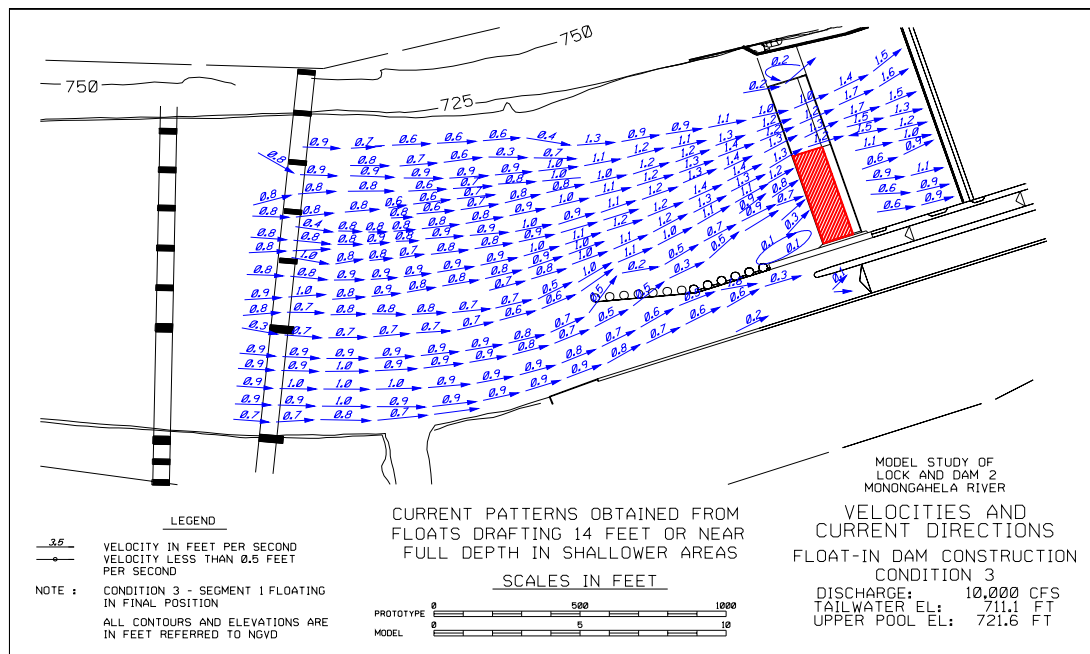


Figure 2. Schematic from Leetsdale to Duquesne.



Figure 3. Pittsburgh District Map showing location of Lower Monongahela Project.

